Application Report
SLUA691 – July 2013

# Measuring Efficiency of the bq25504 Energy Harvesting Battery Charger

*Jeff Falin* *SCBM*

**ABSTRACT**

This application note explains how the data for the bq25504 data sheet efficiency curves was measured.

## Background

Efficiency for output voltage regulating power supplies (that is, ac/dc or dc/dc converters) is typically reported as efficiency vs. load current for a given fixed output voltage and input voltage. The power source to these supplies has an impedance that is significantly lower than that of the converter. Energy harvesting ICs, like the bq25504, take power from sources with output impedances that are relatively higher and that vary with environmental conditions. Therefore, the bq25504 has a circuit that regulates its input voltage to a pre-determined level in order to prevent the source from collapsing while charging the attached storage element (that is, a battery) or during times of excessive resistive load by the system. Called the maximum power point tracking (MPPT) circuit, this circuit extracts the maximum power from the source and delivers as much power as possible to the capacitor on the VSTOR output and any system load. Any additional system load demands must come from the bq25504 attached storage element. Reporting efficiency vs. fixed output load current does not accurately reflect an input voltage regulating energy harvester's optimized state of operation. Hence, energy harvesting ICs, like the bq25504, report efficiency vs. input current for a fixed output voltage and input voltage or efficiency vs. input voltage for a fixed output voltage and input current without a battery attached.

## Test Setup

Instead of reporting efficiency versus output load current as with traditional power supplies, the bq25504 energy harvester boost-based battery charger reports efficiency with fixed input current, self-regulated input voltage, fixed output voltage and the resulting output current. The harvester's storage element (that is, battery) should not be attached to the output. The list of equipment for the measurement is as follows:

1. One source meter capable of being configured as a constant current source
2. One source meter capable of being configured as a constant voltage source
3. One voltage source

Figure 1 shows the recommended test setup.

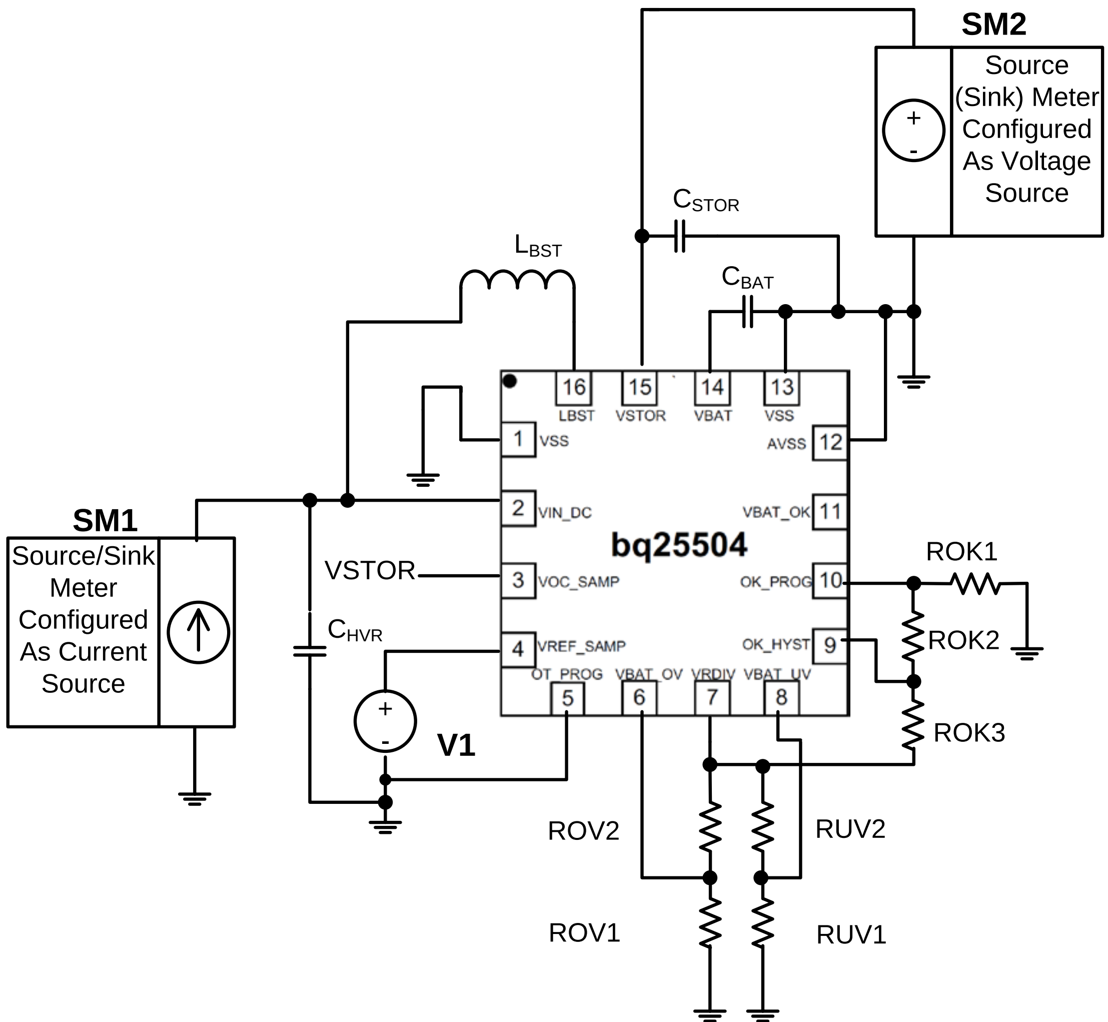


**Figure 1. Bq25504 Efficiency measurement**

ROV1 and ROV2 must be sized so that VBAT_OV is higher than the largest voltage setting expected on SM2. RUV1 and RUV2 must be sized so that VBAT_UV is lower than the lowest voltage setting expected on SM2. ROKx resistors can be at any setting or removed. VOC_SAMP is tied to VSTOR in order to disable the sampling component of the MPPT circuit.

The input source, SM1, is connected to VIN_DC and provides a fixed input current ($I_{IN}$). SM1 should have a compliance voltage set to the intended open circuit voltage of the simulated high impedance source, VOC, but less than 5.5V. For $I_{IN} \leq 500\mu A$, $C_{HVR}$ can remain at 4.7µF per the EVM. For $500\mu A < I_{IN} \leq 100mA$, $C_{HVR}$ must be increased to a low leakage 47uF in order to reduce the input voltage ripple. Otherwise, the source meter will not accurately measure the DC input voltage. Voltage source V1, connected to VREF_SAMP, sets the voltage to which the MPPT circuit will regulate VIN_DC. The source meter (SM1) also measures this voltage ($V_{IN}$). Due to the peak inductor current being clamped at 200mA typical, $I_{IN}$ > 100mA may overpower the input voltage regulation circuit and cause the input voltage to rise to the BAT_OV voltage. The output source meter, SM2, is set to a desired output voltage ($V_{OUT}$), with compliance greater than the expected maximum expected output current, and sinks the resulting output current ($I_{OUT}$). Efficiency can then computed as $\eta = (V_{OUT} \times I_{OUT}) / (V_{IN} \times I_{IN})$.

**IMPORTANT:**

**When measuring nA-µA currents with a source meter, setting the source meter current range no higher than 10X the expected current range and use the normal measurement speed with the filter average count of 50 or more samples is recommended. No scope probes should be attached to any of the pins during the measurement.**

## Efficiency vs. Input Current

The data in Figure 3 was gathered by setting the SM1 current source of V1 to 10µA, the SM2 voltage source to 1.8V and then varying the voltage compliance of V1 from 0 to 3V. The current sweep was repeated with the SM2 voltage source set to 3V and finally 5.5V.

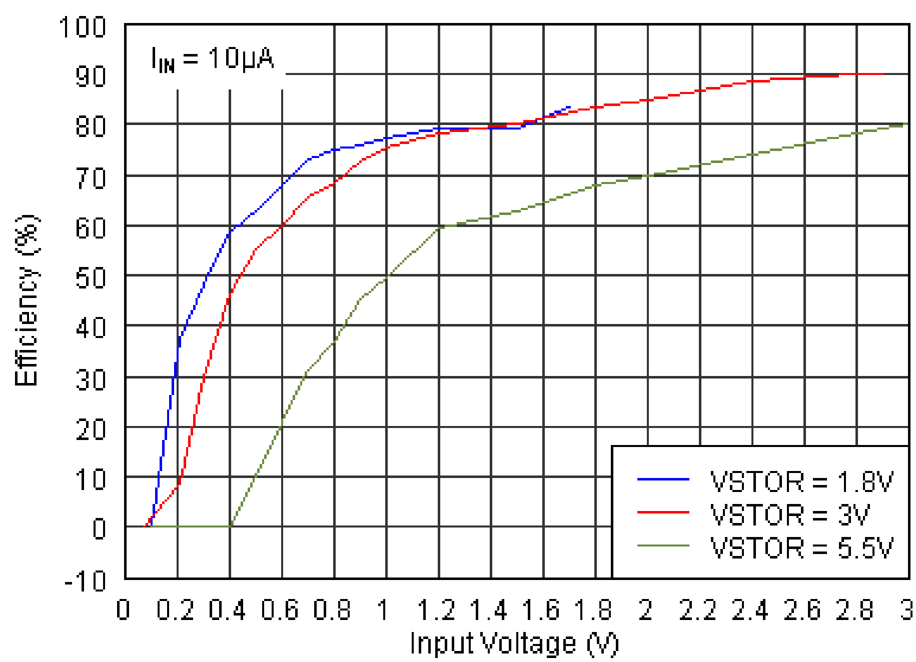


**Figure 2. Example Bq25504 Efficiency vs. Input Voltage**

## Efficiency vs. Input Current Example

The data in Figure 3 was gathered by setting the V1 voltage compliance to 2V, the SM2 voltage source to 1.8V and then varying the SM1 current source from 0.01 to 100mA. The current sweep was repeated with the SM2 voltage source set to 3V and finally 5.5V.

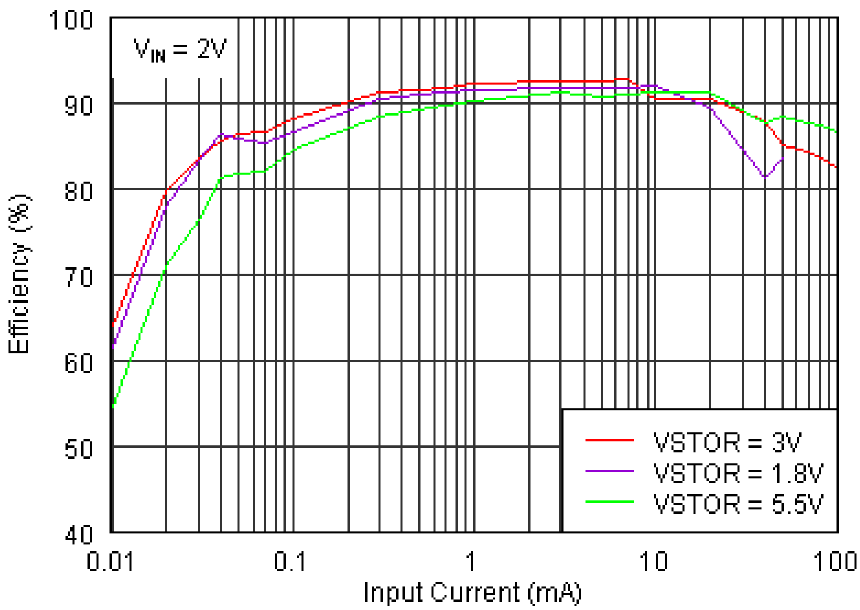


**Figure 3. Example Bq25504 Efficiency vs. Input Current**

## References

1. *Bq25504 Data sheet* (SLUSAH0)

# IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

| **Products** | | **Applications** | |
|---|---|---|---|
| Audio | www.ti.com/audio | Automotive and Transportation | www.ti.com/automotive |
| Amplifiers | amplifier.ti.com | Communications and Telecom | www.ti.com/communications |
| Data Converters | dataconverter.ti.com | Computers and Peripherals | www.ti.com/computers |
| DLP® Products | www.dlp.com | Consumer Electronics | www.ti.com/consumer-apps |
| DSP | dsp.ti.com | Energy and Lighting | www.ti.com/energy |
| Clocks and Timers | www.ti.com/clocks | Industrial | www.ti.com/industrial |
| Interface | interface.ti.com | Medical | www.ti.com/medical |
| Logic | logic.ti.com | Security | www.ti.com/security |
| Power Mgmt | power.ti.com | Space, Avionics and Defense | www.ti.com/space-avionics-defense |
| Microcontrollers | microcontroller.ti.com | Video and Imaging | www.ti.com/video |
| RFID | www.ti-rfid.com | | |
| OMAP Applications Processors | www.ti.com/omap | **TI E2E Community** | e2e.ti.com |
| Wireless Connectivity | www.ti.com/wirelessconnectivity | | |

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265